



Remote Observing with NASA's Deep Space Network

Current status and ongoing developments

Tom Kuiper, Walid Majid, Santa Martínez,
Cristina García Miró, **Ricardo Rizzo**

JPL, ESAC, MDSCC, CAB

July 5, 2012

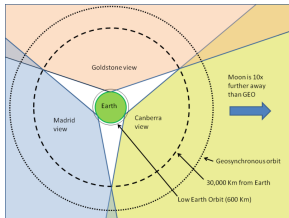


CENTRO DE ASTROBIOLOGÍA
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE

What is DSN?



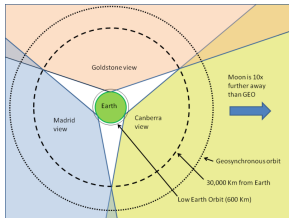
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



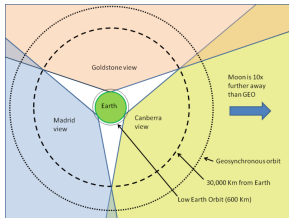
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



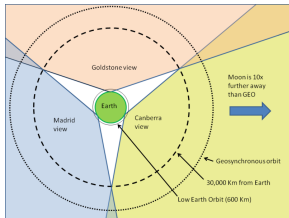
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



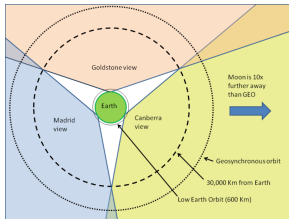
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



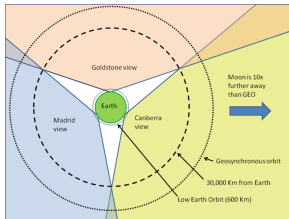
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



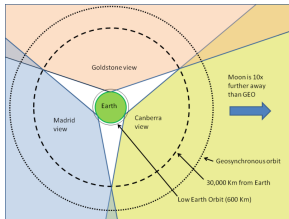
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



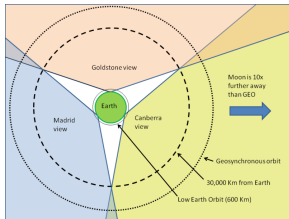
- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



What is DSN?



- DSN = Deep Space Network.
- An international network of complexes (USA, Spain, Australia).
- Each complex hosts several antennas for tracking and communication with spacecrafts up to the very edge of the Solar System.
- Large aperture, high sensitivity needed.
- Ideal and excellent radio telescopes.



DSN Radio Astronomy activities



- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



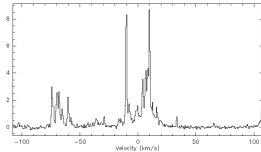
- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

DSN Radio Astronomy activities



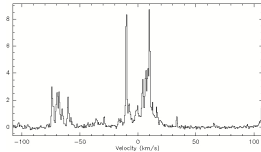
- Therefore, DSN antennas are used as radiotelescopes during $\approx 5\%$ of their operational time
- Single-dish in several bands (up to 50 GHz)
- VLBI / EVN / VLBA stations
- Outreach/Educational projects (GAVRT, PARTNeR) (projects using dedicated antennas).

Science cases



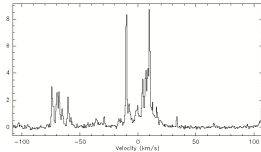
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



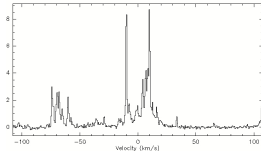
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



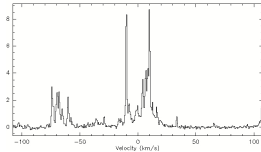
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



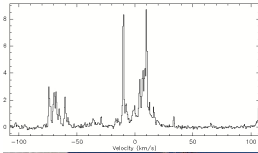
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



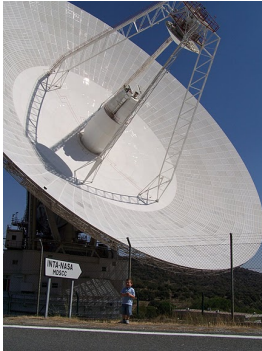
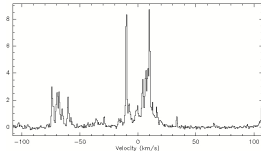
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



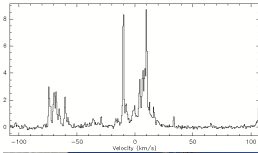
- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases



- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Science cases

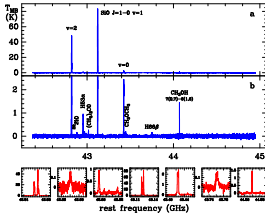


- As single-dish, mostly spectroscopy in L (1.4–1.7 GHz), K (18–26 GHz), and Q (38–50 GHz) bands.
- Some key molecules: H_2O , NH_3 , CCS , CS , SiO , CH_3OH , HC_{2n+1}N , carbon chains, etc.
- Star forming regions, evolved stars, ISM, CSM, PDRs, Solar System, cold clouds, extragalactic, etc.
- Spectral line surveys. Chemical complexity.
- As VLBI stations: both continuum and spectroscopy in astronomy and geodesy.

Radio astronomy operations



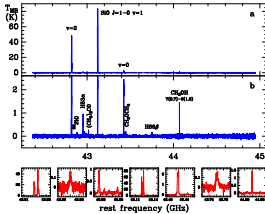
- VLBI observations have to be scheduled with other stations worldwide
- Single dish observations: Impractical to be performed on-site.
- Therefore, all observations scripted or remotely.
- We use the existing networking.



Radio astronomy operations



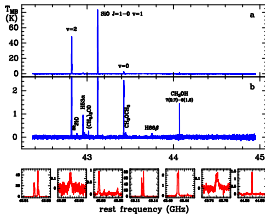
- VLBI observations have to be scheduled with other stations worldwide
- Single dish observations: Impractical to be performed on-site.
- Therefore, all observations scripted or remotely.
- We use the existing networking.

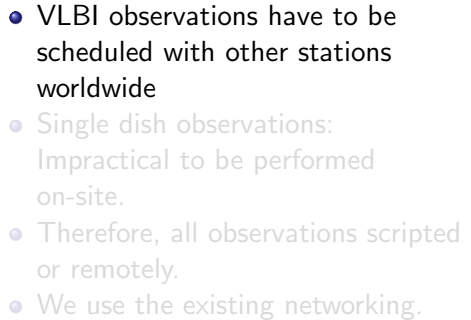


Radio astronomy operations



- VLBI observations have to be scheduled with other stations worldwide
- Single dish observations: Impractical to be performed on-site.
- Therefore, all observations scripted or remotely.
- We use the existing networking.

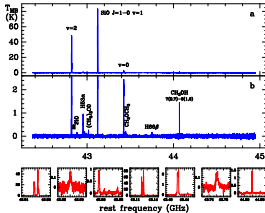


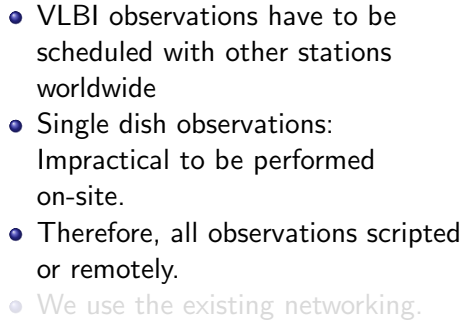


Radio astronomy operations



- VLBI observations have to be scheduled with other stations worldwide
- Single dish observations: Impractical to be performed on-site.
- Therefore, all observations scripted or remotely.
- We use the existing networking.

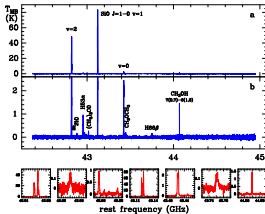




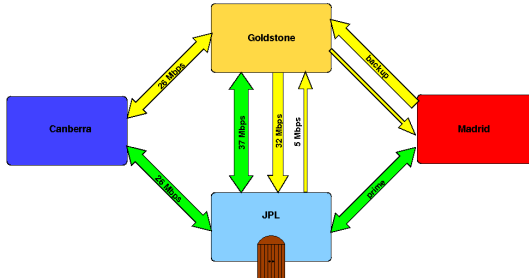
Radio astronomy operations



- VLBI observations have to be scheduled with other stations worldwide
- Single dish observations: Impractical to be performed on-site.
- Therefore, all observations scripted or remotely.
- We use the existing networking.

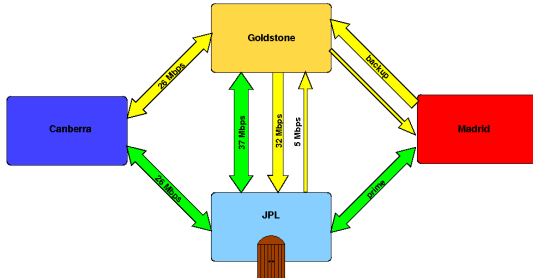


Remote operations: Networking



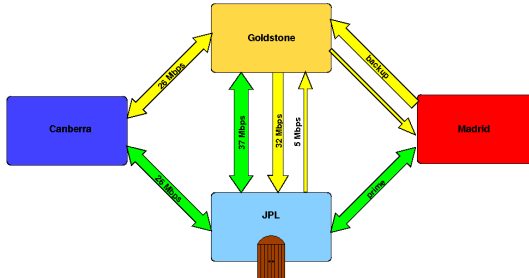
- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*)
- DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.

Remote operations: Networking



- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*).
- DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.

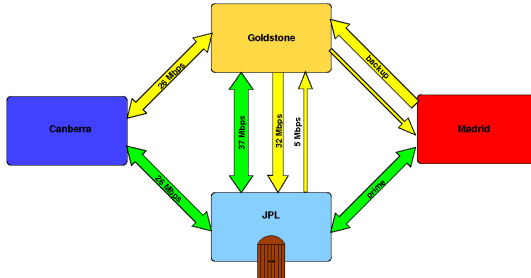
Remote operations: Networking



- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*).

- DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.

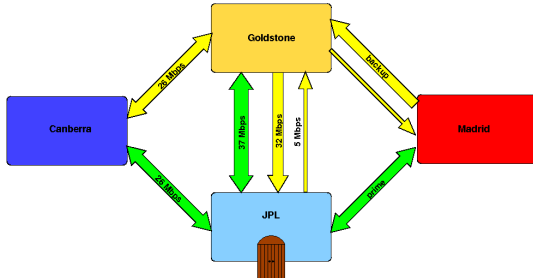
Remote operations: Networking



- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*).

• DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.

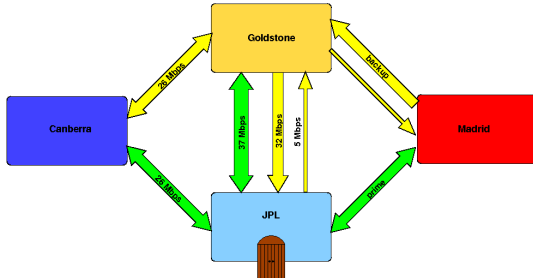
Remote operations: Networking



- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*).

- DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.

Remote operations: Networking



- JPL serves as the center of the DSN.
- Commands sent from mission controls to Space Flight Operations Facility (*FlightOps*).
- DSN R/A computers are on a subnet of the FlightOps, which can only be accessed through a secure gateway at JPL.





- Custom scripts:
ssh-tunnel goldstone rac14a
- Mounting remote FS:
rmount 50015-RA /home/kuiper
- Tunnel is now open to localhost.



- Custom scripts:
ssh-tunnel goldstone rac14a
- Mounting remote FS:
rmount 50015-RA /home/kuiper
- Tunnel is now open to localhost.



- Custom scripts:
ssh-tunnel goldstone rac14a
- Mounting remote FS:
rmount 50015-RA /home/kuiper
- Tunnel is now open to localhost.



- Custom scripts:
ssh-tunnel goldstone rac14a
- Mounting remote FS:
rmount 50015-RA /home/kuiper
- Tunnel is now open to localhost.



Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere
 - The same for all GUIs
 - Put all the control in your hands
 - Possibility of sharing desktop
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere
 - The same for all GUIs
 - Put all the control in your hands
 - Possibility of sharing desktop
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Remote operations: The graphical solution



- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

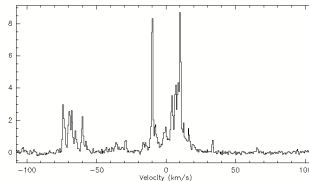
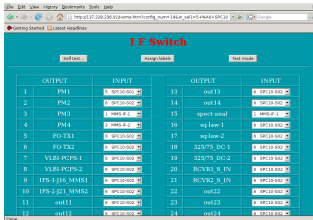
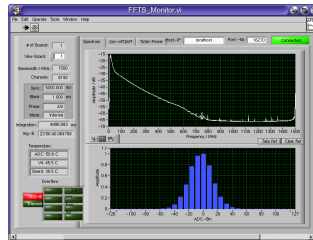
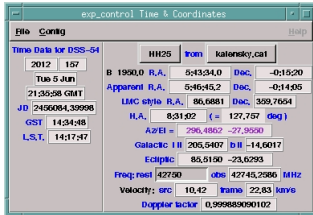
Remote operations: The graphical solution



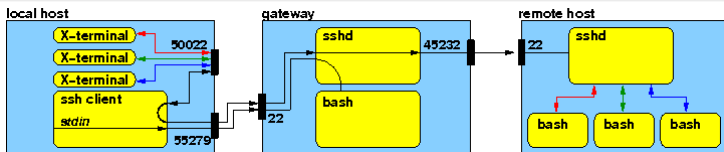
- Several procedures to run GUIs remotely, based on `vnc` and `nx`.
- These GUI-based software are good solutions:
 - The same software everywhere.
 - The same for all DSN.
 - All the control in your hands.
 - Possibility of sharing desktops.
- but ...
- **painfully slow** when network traffic is high, operating through a low data rate link (even some DSLs).

Some examples:

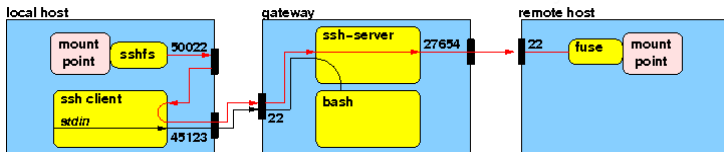
Antenna control, hardware setup, data.



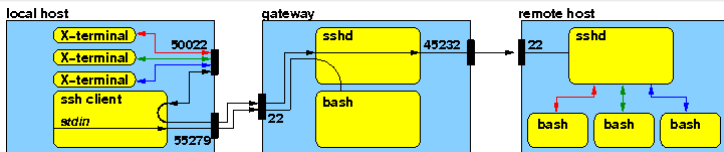
Two approaches: first



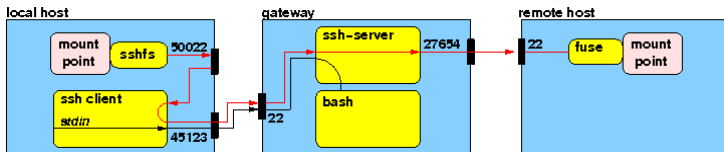
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



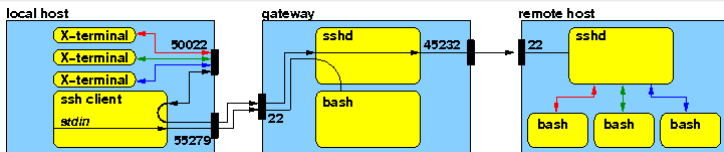
Two approaches: first



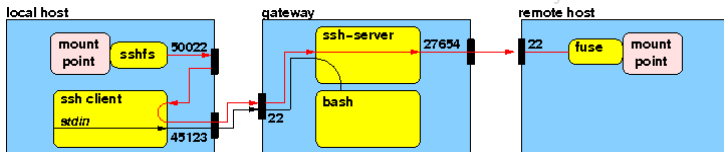
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



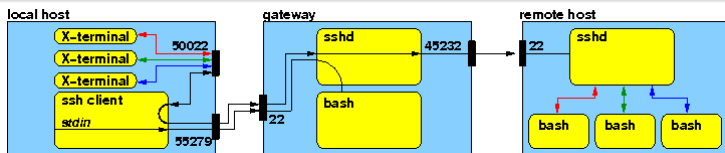
Two approaches: first



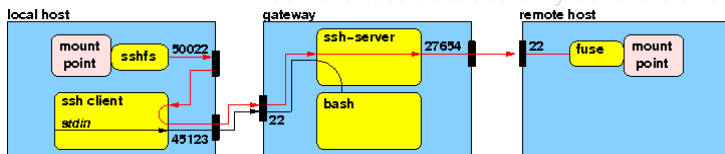
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



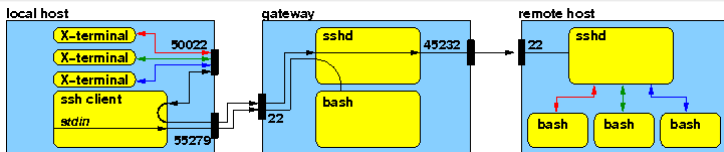
Two approaches: first



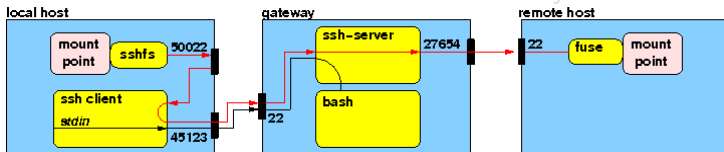
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



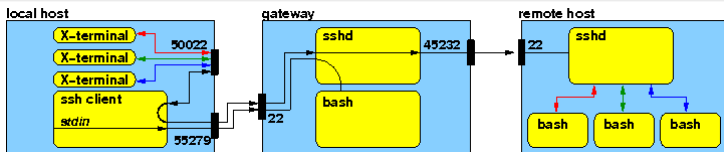
Two approaches: first



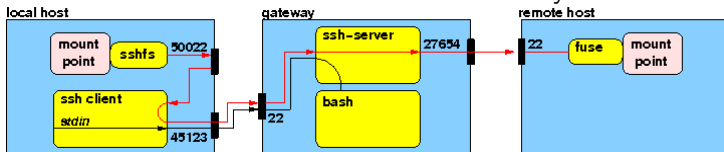
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



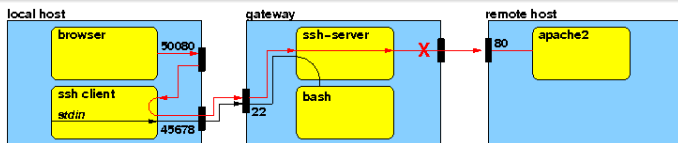
Two approaches: first



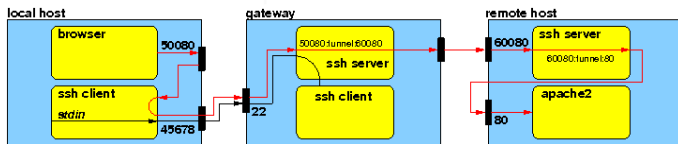
- To run a remote text-only program from within a local GUI-based application.
- The local program can read the remote programs stdout or a file being written by the remote program.
- Both are fast because only text is transferred.



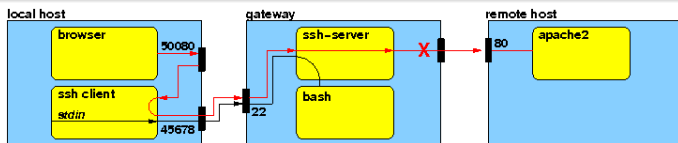
Two approaches: second



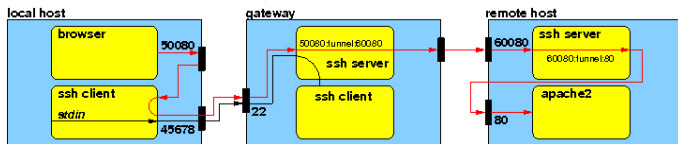
- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



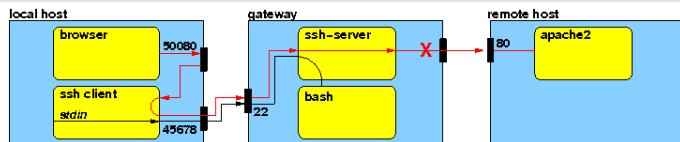
Two approaches: second



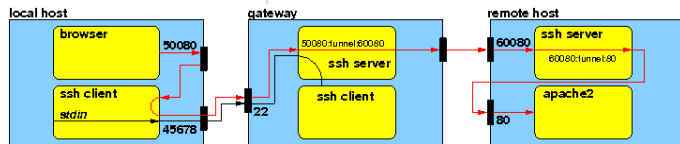
- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



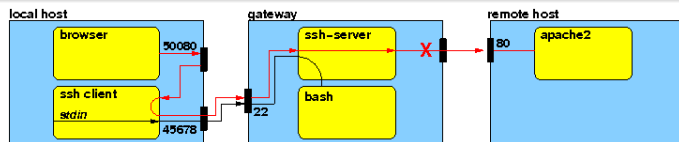
Two approaches: second



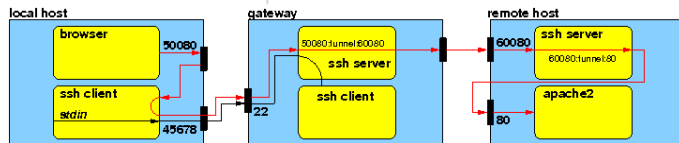
- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



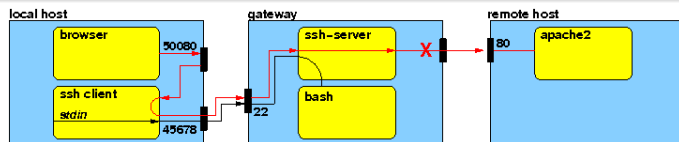
Two approaches: second



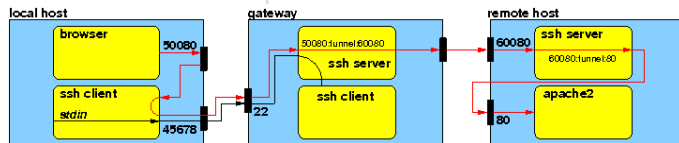
- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



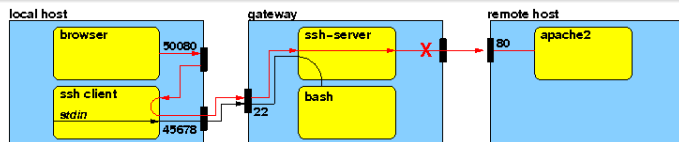
Two approaches: second



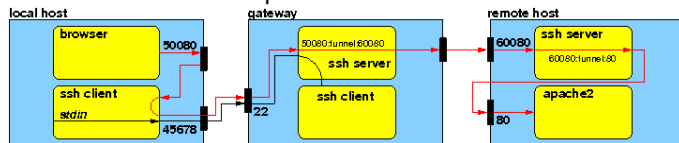
- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



Two approaches: second



- Another way: to communicate with a remote server via a dedicated port.
- Tunneling to certain remote ports, like the WWW port, is often not allowed by firewall rules.
- The workaround is to forward the tunnel request to the remote host.



Concluding remarks

- DSN operates three complexes worldwide for radio astronomy, during some 400 hr/yr/antenna.
- Different programs to do radio astronomy. Many science cases.
- Scripted and remotely operations. Sharing desktops solutions.
- To overcome low-velocity networking, we are implementing some new approaches, based on text-based traffic and dedicated ports.
- **IMPORTANT:**
For deep information, see full explanation in the proceedings.

Concluding remarks

- DSN operates three complexes worldwide for radio astronomy, during some 400 hr/yr/antenna.
- Different programs to do radio astronomy. Many science cases.
- Scripted and remotely operations. Sharing desktops solutions.
- To overcome low-velocity networking, we are implementing some new approaches, based on text-based traffic and dedicated ports.
- **IMPORTANT:**
For deep information, see full explanation in the proceedings.

Concluding remarks

- DSN operates three complexes worldwide for radio astronomy, during some 400 hr/yr/antenna.
- Different programs to do radio astronomy. Many science cases.
- Scripted and remotely operations. Sharing desktops solutions.
- To overcome low-velocity networking, we are implementing some new approaches, based on text-based traffic and dedicated ports.
- **IMPORTANT:**
For deep information, see full explanation in the proceedings.

Concluding remarks

- DSN operates three complexes worldwide for radio astronomy, during some 400 hr/yr/antenna.
- Different programs to do radio astronomy. Many science cases.
- Scripted and remotely operations. Sharing desktops solutions.
- To overcome low-velocity networking, we are implementing some new approaches, based on text-based traffic and dedicated ports.
- **IMPORTANT:**
For deep information, see full explanation in the proceedings.

Concluding remarks

- DSN operates three complexes worldwide for radio astronomy, during some 400 hr/yr/antenna.
- Different programs to do radio astronomy. Many science cases.
- Scripted and remotely operations. Sharing desktops solutions.
- To overcome low-velocity networking, we are implementing some new approaches, based on text-based traffic and dedicated ports.
- **IMPORTANT:**
For deep information, see full explanation in the proceedings.